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AMERICAN JOURNAL OF OPTOMETRY

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A PHILOSOPHICAL STUDY OF OCULAR RESPONSES*

William Henning, N.D., Opt.D., F.A.A.O.
Fargo, N. D.

The object of this paper is to question the soundness of our present philosophy upon which optometry is based. Especially that phase which deals with the presently accepted interpretation of symptoms.

However, it would be unsafe to interfere with the present foundation unless we have something to substitute which has proved to be superior. Therefore, I shall confine myself to those phases which I can first prove to be wrong, and then offer a solution that will stand up under the most crucial tests known to science today.

If my premises are correct, then optometry, next to ophthalmology, stands indicted today of having done much more harm than good. In other words, we have increased visual efficiency and reduced ocular discomfort at the expense of physical coordination.

Let us discuss first the question of what is alluded to as a "refractive error" or "muscular anomoly" and whether it is ever the cause of discomfort? I take the stand that it never is, and shall attempt to prove it. Second, does a plus lens correct so-called hyperopia? or does a minus lens correct myopia? Again, my answer is in the negative. Another question that may be raised, is the plus or minus lens acceptance which improves vision positive evidence that it should be prescribed for constant wear. To which I reply, not necessarily.

Also, is the amount of plus which improves vision and simultaneously reduces esophoria, and relieves ocular discomfort an indication of its need? And again, I say positively not. In fact, I fortify my statement by saying it is definitely contra-indicated at all times, for a similar reason as that a minus lens which reduces exophoria, improves vision and relieves discomfort and in spite of it, it is contra-indicated. Both, plus and minus lenses under the above circumstances can only intensify the cause of discomfort and increase the error. Next come the questions of the relationship between accommodation and adduction. Which is more important, to stimulate accommodation or to inhibit adduction or vice versa? For example, in a given case of myopia, hyperopia, squint

*An abridgment of the material presented before the American Academy of Optometry at Rochester, New York, June 24, 1937.

or heterphoria, and why? If my conclusions are correct, perhaps the gravest and by far the most common error we have made is that of prescribing plus spheres for permanent wear in functional "hyperopia." Let us take a case wherein it has always been the custom of inhibiting all of the possible accommodation. As an example, I employ a case of convergent strabismus of thirty prism diopters, and with it we have three diopters of manifest "hyperopia." If we try to account for this condition within the ocular mechanism, and assume that the over convergence is due to hyperopia, we would have to uncover about two diopters of so-called latent hyperopia because, the normal ratio is two and one-half diopters with fifteen prism diopters of convergence with 60 P.D. Theoretically speaking at least, that should be the amount. Still another question that may be raised is, do we always accommodate two and a half diopters at sixteen inches in case of "emmetropia" and orthophoria? Again I take a decidedly negative stand, and shall now proceed to prove my contentions.

Everything spherical in nature when not interfered with, or removed from its normal environment will remain spherical. For example: Water, and other liquids when released into space, a drop at a time, immediately assumes spherical form.

Therefore, is it not logical to a ssume that the eyeball, suspended as it is, in the orbit, surrounded by a resilient mass forming a cushion, to become spherical, and remain so, when unrestrained? There is ample evidence to support that contention, because there are plenty of cases on record in which astigmatism developed after the age of ten when the eye is almost completely developed insofar as form is concerned. There are also enough cases on record where astigmatism disappeared in adults. I mention astigmatism especially because it is more likely to be considered as being a structural error, since it can definitely be measured as such. This warped condition then which we call astigmatism is most likely due to disturbances in and/or outside of the body which interferes with tissue formation. In view of the evidence at hand it is certainly more reasonable to assume that what has been termed hyperopia and myopia, meaning long and short eyeball respectively, is mainly a hypo-tonicity of the contracting phase or hyper-tonicity of the dialating phase of the autonomically controlled viscera in case of hyperopia, and the opposite in myopia. Or perhaps a similar explanation would be, a reciprocal hypo and hyper tonicity in one, and of course, the opposite in the other.

At one time it was not an uncommon practice to prescribe base in prism for constant wear in exophoria cases and base out in case of esophoria. This was found to be incorrect because it aggravated the condition instead of improving it, and for a number of years prisms were regarded as extremely detrimental. Years later, however, some practitioners again started to use prisms but, instead of prescribing them

for constant wear, they employed them for the purpose of what was then called prism exercises, and instead of base in for exophoria and base out for esophoria they reversed the bases in the very opposite direction. It is generally contended, orthoptically speaking, that prisms produce the greatest and most direct effect on the somatic phase of the nervous system. While on the other hand, lenses have a greater and more direct effect on the autonomic phase by way of the accommodative reflex. If this is true, and prisms produce a detrimental effect when prescribed base in for constant wear in exophoria, and base out in esophoria, why should not the same rule hold good when plus lenses are prescribed for constant wear in hyperopia, and minus lenses in myopia. I insist that it does, because practical application proves my contention. Assuming that what we call exophoria is a lowered tonicity of the voluntary or striped muscles and esophoria an hyper-tonicity.

Furthermore, if what we designate as hyperopia is hypo-tonicity of the smooth or involuntary muscles, and myopia an increased tonicity, then our classifications would be as follows: 1. Hyperopia with normal phorias represent visceral hypo-tonicity. 2. Myopia with normal phorias is analogus with visceral hyper-tonicity. 3. Emmetropia with esophoria means skeletal hyper-tonicity. 4. Emmetropia with exophoria points to skeletal hypo-tonicity. 5. Hyperopia with esophoria means visceral hypo- and skeletal hyper-tonicity. 6. Myopia with exophoria, equals visceral hyper- and skeletal hypo-tonicity. 7. Hyperopia with exophoria means visceral and skeletal hypo-tonicity. 8. Myopia with esophoria means visceral and skeletal hyper-tonicity. For this purpose emmetropia is to be understood as a condition where plus .25 to plus .75 or average plus .50 will not blur distant vision. Hyperopia, an eye which will accept more plus than an emmetropic eye, and myopia, an eye which will accept less plus than the amount required in emmetropia.

Since the normal ratio between accommodation and adduction should be two and one-half diopters to fifteen prism diopters for a pupilary distance of sixty millimeters, we shall consider the phorias on this basis. For example: In case of two and one-half diopters of myopia, the case is considered exophoric unless there is more than fifteen prism diopters of esophoria. On the other hand, in case of two and one-half diopters of hyperopia, it is considered esophoria unless there is more than fifteen prism diopters of exophoria.

Our present philosophy makes it necessary to account for esophoria, exophoria, high and low retinoscope findings, high or low blur out points and low ductions within the ocular mechanism while in actuality the underlying cause rarely if ever resides there. In fact, quite frequently the actual primary cause is entirely outside of the body, if not always.

It is my contention that there are only two general causes in any functional abnormality in the human body, namely: Physiological and/or emotional. Since the ocular mechanism contains the most and

greatest variety of nerve endings of any bodily organ and of both general phases of the nervous system, it becomes possible for the optometrist to institute a variety of functional changes throughout the entire body. And since the cause of ocular discomfort is almost always outside of the visual apparatus but manifests itself therein, it is imperative that we consider our corrective procedure from more than one viewpoint. Fortunately, in the majority of ocular discomfort cases satisfactory results can be obtained by merely changing the ocular stimulus with lenses and prisms. This may be accomplished in two ways, one is by changing the course of light, and the other by changing its quality or constituency as well as its quantity. In all cases it is better, and most cases necessary to combine the indicated orthoptics with what I choose to call the proper lens therapy.

This is done by prescribing combinations of lenses and prisms for constant wear but they are changed according to the changes in symptoms as determined by optometric tests.

The following examples will illustrate what I mean; to begin with, we base all other symptoms, on the distance phoria and the static refraction, which in turn are established on the accepted normal relationship between accommodation and adduction, viz.: Two and one-half diopters of accommodation with fifteen prism diopters of triangulation. If we then have two and one-half diopters of myopia, which for this purpose indicates that amount of visceral hyper-tonicity, there should be associated with it fifteen prism diopters of esophoria in order to have a balanced relationship. So, in addition to the indicated orthoptics the procedure in lens therapy would be as follows: Inhibit accommodation with enough plus so a focal point never reaches the macula at any time, which would be three diopters, provided the patient does not bring objects closer than sixteen inches. At the same time we stimulate adduction by incorporating base out prism in the lenses gradually, being guided by the patient's distance base out recovery point, and increase the amount as indicated until we reach a balance, which would be fifteen prism diopters in this case. If, however, the myopia reduces during this process, less prism will be required. I have touched on esotropia and myopia first because we have always been more interested in reducing those conditions. However, my contention is, that it is much more important to reduce hyperopia than myopia because, a visceral hypotonicity is much more apt to jeopardize the general well being of the individual than the opposite condition. Furthermore, the greater majority of our patients are of that type.

The procedure in esotropia is just the opposite of that pursued in myopia. That is, we prescribe minus or less plus to stimulate accommodation and incorporate base in prism to inhibit adduction. Any case should be made comfortable with orthoptics before the reconditioning is started.

In conclusion, if what I have stated is correct, we will employ

lenses and/or prisms for reconditioning and for constant wear as a last resort only, to enable the patient to see clearly and singly. The spectacle vending salesman will then be eliminated by the professional optometric practitioner, who will be looked upon by the public as an advisor, counsel and consultant to the medical and drugless physician, whenever ocular disturbances, complications and syndromes appear during the general health examination or periodical check-up.

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AN EXPERIMENTAL STUDY OF OCULAR FATIGUE*

I. General Fatigue

Introduction

The fatigue problem has been studied by many investigators along different lines. Numerous researches have been carried out and the results reported in various publications, but to date there is little agreement as to the meaning and method of measuring fatigue as well as to the interpretation of the experimental results.

A. *The Meaning and Nature of Fatigue*

What is fatigue? It is defined by some as a decrease in the capacity of a single muscle or a group of muscles to perform work, or as the lowering of the capacity for work in the normal individual in the abscence of emotive stimuli. There are three ways to estimate the muscular fatigue index.

1. A muscle may be forced, by natural or artificial stimulation, to work against a heavy load and either the time required for complete loss of contractility or the time required for recovery of the original irritability is taken as the index of fatigue.

2. A muscle may be forced to work against a moderate load and the time required either for exhaustion or for the return to normal contractility may be considered as the fatigue index. This differs only from the method mentioned first in the selection of the weight.

3. A muscle may be forced to work against a load so chosen that the height of the individual muscular contractions are reduced but reach a constant level beyond which further reduction does not take place. Here either the height of the fatigue level or the time required to reach that level is chosen as the fatigue index.

B. *Theories of Fatigue*

1. *Physical Theory.* Spaeth[1] in discussing this problem approaches it from an equilibrium standpoint. He contends that organisms have the power of self-recuperation. This is in contrast with inanimate objects like man-made machines which are not capable, by themselves, to replace the wear and tear of their parts. The organism has a double process of metabolism: (1) katobolism and (2) anabolism. These two processes constantly tend to balance each other, and is known as the physiological equilibrium, which may be represented as:

Energy at	Katabolism ⟶	Energy at
High Potential	⟵ Anabolism	Low Potential

This scheme indicates that neither katabolism or anabolism is ever present alone, and that once the degradation of energy has begun a reaction in the opposite direction sets in, i.e., a tendency to deposit energy at a high potential is developed.

The relation between work and rest Spaeth represents by a similar scheme.

Energy at	Work ⟶	Energy at
High Potential	⟵ Rest	Low Potential

From a chemical standpoint *work* energy reduces some of the total available energy to low potential and *rest* restores energy to a high potential.

2. *Chemical Theory.* According to this theory fatigue is caused by using up the glycogen and the production of lactic acid. This is the most accepted theory and is substantiated by the fact that when isolated fatigue

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*This experiment was carried out at the Physiology Laboratories of the Medical School at the University of Minnesota. It is an abbreviation of a lecture presented before the Minnesota Academy of Optometry September 27, 1937.

We wish to acknowledge our indebtedness to Prof. F. H. Scott of the Physiology Department, to Prof. M. A. Tinker of the Psychology Department for their helpful suggestions and criticism, and to Prof. Alan E. Treloar of the Biometry Department for his assistance with the statistical work.

substances are injected into rested muscles all the fatigue phenomena are produced there, as they would be produced under ordinary methods of work.

3. *Histological Theory.* Hodge experimentally found (31) that the nerve cell actually shows definite structural changes due to its activity. In some instances there was an actual decrease in the size of the cell, a loss of stainable substance, a loss of other protoplasmic substance, causing a vacuated condition of the cell and a ragged and more sharply defined contour. In recovery the cell returns to its normal shape and structure.

C. *Fatigue Tests*

Different types of tests are being used to study fatigue, the validity of most of the tests is open to question, some of these tests are:

1. Martin Spring Balance Test.

This is an ordinary flat faced spring balance with a scale capacity of 200 lbs. marked in 2-lb. units and is equipped with a self-registering index.

2. The Strength Weight Relationship, i.e., a certain ratio is maintained between the strength and weight.

3. Comparison of amount of work done at the beginning and at the end of the shift.

(a) In easy jobs the showing is better in the end than at the beginning.

(b) In jobs requiring moderate exertion, the stronger workers will do better in the end than at the beginning, but the weaker workers will not do as well at the end.

(c) In hard work all workers will do less at the end than they did in the beginning.

4. *The Psychophysiological Tests.* These tests have as their object the procuring as some simple measurement of fatigue to be applied before and after carrying out a day's work. The "out-put" is the factor utilized in this test.

5. *Statistical Method.* This is used mostly in pedagogy and industry. The output rate is the important factor in this method. The output curve is affected by three factors: (a) The diurnal variation of the individual's capacity; (b) The state of the "energy level"; (c) Individual differences in fatigue development, i.e., persons who perform the same type of work are not affected by fatigue in the same degree.

6. *Chemical Tests.* With this test, certain chemical changes which take place in the body as a result of "chemical" activity are measured. It has been found that a very definite relationship exists between the amount of work performed and the quantity of lactic acid produced. Lactic acid urine test. Lactic acid is present in the urine after extreme muscular exercise in ammunition workers. They show a greater increase

in acidity in the evening than in the morning while the reverse was true in the control test.

7. *Ergograph Test.* This test is the most universally used. Mosso, Bose, Reid, Spaeth and others used the ergograph extensively in their investigations, the results are readily observed and easy to interpret. The ergograph writes the simplest type of fatigue curves. These curves show an (a) initial rise of efficiency, (b) brief period of maximum efficiency, (c) and an eventual decline. This decline will usually be arrested at the fatigue level. The height of the fatigue level varies inversely with the rapidity of the rhythm of contraction. For example, if after a muscle had contracted for six minutes at a rate of $\frac{C}{R} = \frac{1/2 \text{ sec.}}{3/2 \text{ sec.}}$ the rhythm was changed to $\frac{C}{R} = \frac{1/2 \text{ sec.}}{19/2 \text{ sec.}}$ the muscle will promptly rise to its original level as long as the slower rate prevails. C = Contraction. R = Rhythm.

8. *Sensation of Fatigue.* This is one of the least valid tests for fatigue. Often times one may have all the sensations of fatigue and yet no fatigue can be discovered by any other test and vice versa.

D. *Experimental Findings*

Mosso[24] was one of the pioneers to study fatigue experimentally. He used the ergograph (illustrated in Fig. 1) and obtained a number of fatigue curves and contractures. He claims that fatigue curves are

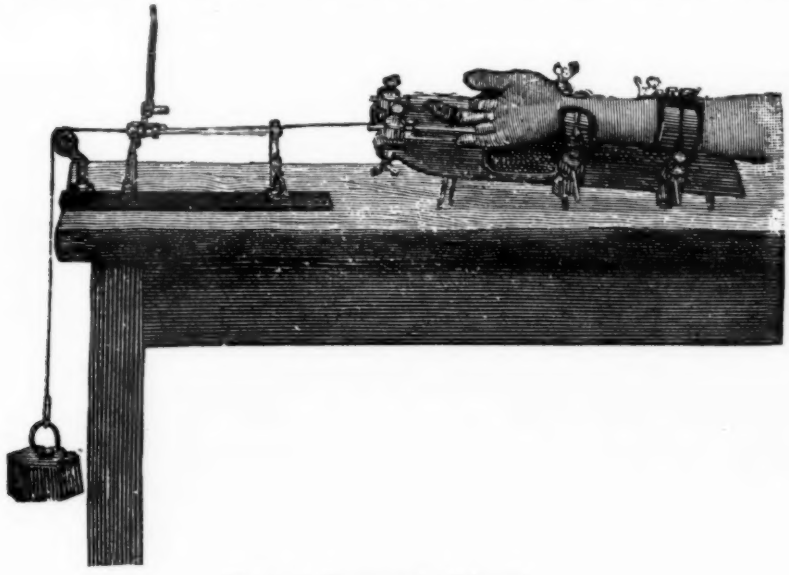
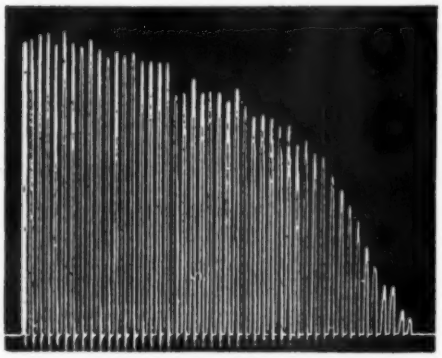


Figure 1 Ergograph (Mosso).

constant and record different individual characteristics. Figs. 2 and 3 illustrate normal fatigue curves of different individuals.



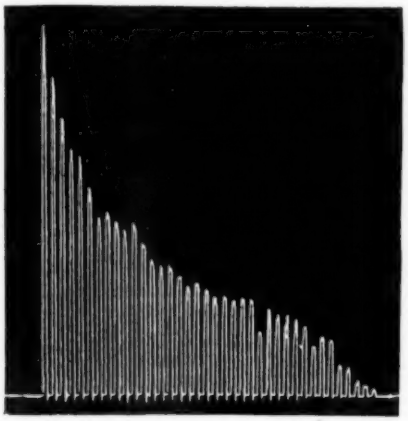


Figure 2—Normal fatigue Curve (Mosso). Figure 3

Factors which Modify Fatigue Curves: (1) Rest. (2) Emotion. (3) Mental Work. (4) Mode of Living. (5) Seasonal Changes. These factors will not only change the form of the curve but the number of contractions as well. Exercise produces a curve having nearly twice the number of contractions produced in the curve preceding exercise.

In producing his fatigue curves Mosso used voluntary and involuntary contractions. In the latter type he applied electrical stimulation to the nerve or directly to the muscle. Reid[2] in his study of fatigue found that it was impossible to induce in man during a period of two hours complete fatigue in the flexor sublimus digitorum. He used a faradic stimulation repeated at the rate of 80 per minute using a load of 3 kilos, i.e., fatigue was not induced by nearly 10,000 contractions of the muscle by means of peripheral stimulation through the nerve trunk or the body of the muscle. Reid found that the rate of contraction is an important factor in producing fatigue, i.e., when the voluntary contraction is slow from 12 to 80 per minute the power of muscle contractions to peripheral stimulation is not impaired, if however, the contraction rate is from 120 to 200 per minute there is a marked impairment of the contractile powers of the muscle. Reid also found that when a muscle is fatigued by voluntary contractions it still responds to peripheral stimulation, but the reverse is not true, this is in contrast to the findings of Mosso and Lombard, who claim that a muscle fatigued by peripheral stimulation will respond to voluntary stimulation.

2. *Staircase Phenomenon and Contracture*

The phenomenon of contracture was studied experimentally by Mosso,[26] Reid,[2] Gruber,[4] Davis,[5] and Verworn.[32] Reid found that if

fatigue is induced rapidly by active voluntary contractions with different weights (0.5 to 2.5 kilos) at rates of 120 min. a certain amount of tension is developed in the muscles, as can be seen by the increasing failure of the recording lever to return to its original level. Davis in a study tried to determine if the staircase phenomenon is absent in fatigue intact mamalian skeletal muscles contracting isometrically, and whether this phenomenon is dependent upon the increased duration of the contraction phase in the warm blooded animals, as is believed to be the case in cold blooded animals. He concluded that the staircase phenomenon was not due to the inertia of the levers or to a prolongation of contraction phase, but that it is due to an increase in the irritability of the muscle which is probably the result of the accumulation of small amounts of fatigue products. Lack of circulation through the muscle does not appreciably alter the staircase phenomenon. Verworn claims that increased height in the "Treppe" is not a sign of increased efficiency of the muscle but is rather the first sign of the onset of fatigue.

3. *Laws of Fatigue and Exhaustion*

Mosso gives this as the law of fatigue. The curves of fatigue of a muscle which contracts at regular intervals and with equal strong induction shocks, is represented by a straight line. The difference in the height of contractions is less when the intervals of time are greater, i.e., the height of contractions diminish more rapidly the more rapid is the rhythm with which they are produced.

Work performed by a muscle already fatigued acts on that muscle in a more harmful manner than a heavier task performed under normal conditions. When a muscle like the flexor completely exhausted requires two hours for complete recovery, if that same muscle is only half way exhausted it takes ¼ of the time (half hour) to recover. This would tend to indicate that less energy is used up during the first half of the work period than in the last.

When a muscle is not completely fatigued or exhausted it will perform twice as much work than it would if it were worked to complete exhaustion.

4. *Central and Peripheral Fatigue*

Fatigue is peripheral says Spaeth[1] when the conduction of the impulse over the end plate is blocked by the metabolity. Sherington holds that fatigue is due to synaptic resistance. He claims that it is to the synapse, where the sensory neuron comes into contact with the motor neuron, that this initial fatigue must be ascribed. Central fatigue may be experimentally demonstrated to be at the synapses of the afferent or intermediary neurous. The part that the neurom bodies hold in fatigue, he claims, is not definitely known.

There is some disagreement as to the effect of mental and muscular activity. While most students of fatigue agree that excessive muscular work will cause fatigue which acts as a safe guard, this is not true in the

case of mental activity. McDowall,[15] for instance, holds that excessive mental activity can be carried on indefinitely.

5. *The Work of Hill*

Hill[29] carried out extensive and novel research on fatigue. He considers the human body as a machine and it possesses, he claims, machine like properties. It obtains its energy from food and the principle of conservation of energy applies to it as it does to other machines.

E. *Physiological Reactions*

It was pointed out earlier that oxygen plays an important part in the development and recovery of fatigue, in order to obtain the oxygen required by the working muscles, certain physiological changes take place.

1. Respiration must increase the oxygenated blood flow through the lungs and the muscles must keep pace with the requirements of the moment.

2. The respiratory centers may be stimulated by the lack of oxygen.

3. Exercise, if pushed too far may result in the delivery of lactic acid from the muscles to the blood stream.

4. The pulmonary ventilation range is very large during a short period of severe exercise, such as a 100 yard race. It may lead to a ventilation of 150 liters per minute. It is usually from 100 to 120 liters per minute in less severe exercise.

F. *The Locus of Fatigue*

In the study of fatigue it is of importance to take into consideration the fundamental physiology of the muscle, nerve and central nervous system, in correlation with the information of other bodily processes which may influence the development of fatigue. Experimental studies have shown the "neuron bodies" are not the site of fatigue. It was also shown that the "nerve trunks" are indefatigable. Keith Locas has shown that for .003 sec. after the passage of an impulse the nerve trunk will not conduct another impulse. Sherington too has shown experimentally that fatigue is not in the nerve itself but in the synapse.

Seham[17] holds that while the nerve is indefatigable it may stimulate the signs of fatigue such as (a) increase in excitation time, (b) in conduction time, (c) duration of its refractory period.

When an impulse can not pass due to synaptic resistance only two alternatives are possible in order to resume contraction: (a) to increase the strength of the impulse so as to break down the synaptic resistance, (b) to experience some sudden general influence which may lower the synoptic resistance and permit the normal impulse to pass through to the muscle.

The relative fatigueability for the structures is in the following descending order: (a) The Motor end Organ, (b) The Muscle, (c) The Nerve Fiber. Local fatigue is claimed to reside in the end organ. Fatigue of the synapse or motor end plates expresses itself by the failure to permit

impulses to pass, and in the muscle cells by failure to recognize impulses which may reach them.

II. Ocular Fatigue

In the first part of this discussion we tried to describe briefly the mechanism of production and recovery of fatigue. In this, the second part, we shall discuss ocular fatigue. The physiological laws and phenomena which apply to general fatigue also apply to ocular fatigue.

A. *Studies in Ocular Fatigue*

1. *Method of Measuring Ocular Fatigue*

Not much experimental work has been carried out on this subject. There are a few studies reported but in the main there is little agreement about the results obtained and their interpretation. The method employed in testing ocular fatigue is open to question. Duane[34] claims that the near point is not a reliable measure of fatigue because it is too variable. It may vary from 6-7 diopters in young persons and 2-3 diopters in adults. The writer[48] investigated this subject and his findings are in agreement with those of Duane. Lancaster and Williams also criticized the near blur point method, because after the subject holds the print for a little while the blur disappears and the print becomes legible again, i.e., a certain amount of accommodation is soon regained and that the punctum praximum can be brought considerably nearer.

a. *Ophthalmic Ergograph*

Howe[44] in the early part of this century devised an ergograph for testing fatigue of accommodation. This is illustrated in Fig. 4. At first it was a very crude affair, but improvements were constantly made and at the present time it is quite an elaborate instrument. It works automatically, recording both accommodation and convergence on the same smoked drum, and one is thus able to see at a glance the fatigue curve and to determine whether accommodation or convergence begins to fatigue first (This is shown in Figs. 5 and 6.) Berens and Stark[43] made considerable use of this type of ergograph of late and they report, that using the amplitude of accommodation as a criterion of fatigue, they find that of several hundred cases studied, in 30.8 per cent of the cases the amplitude of accommodation has decreased, in 40.5 per cent the accommodation remained constant and in 28.7 per cent accommodation actually increased, in other words evidence of fatigue was revealed in only about 30 per cent of the cases. They also claim that fatigue and diplopia will set in in some cases in two minutes and in six minutes in others. It is to be regretted that they do not describe the technic they use which enables them to get fatigue in a much shorter time than recorded by other investigators.

C. *Wagner's Apparatus for Measuring Fatigue*

Wagner[41] devised an ingenuous method for testing ocular fatigue. He used a complicated electrical hook up with which he could measure

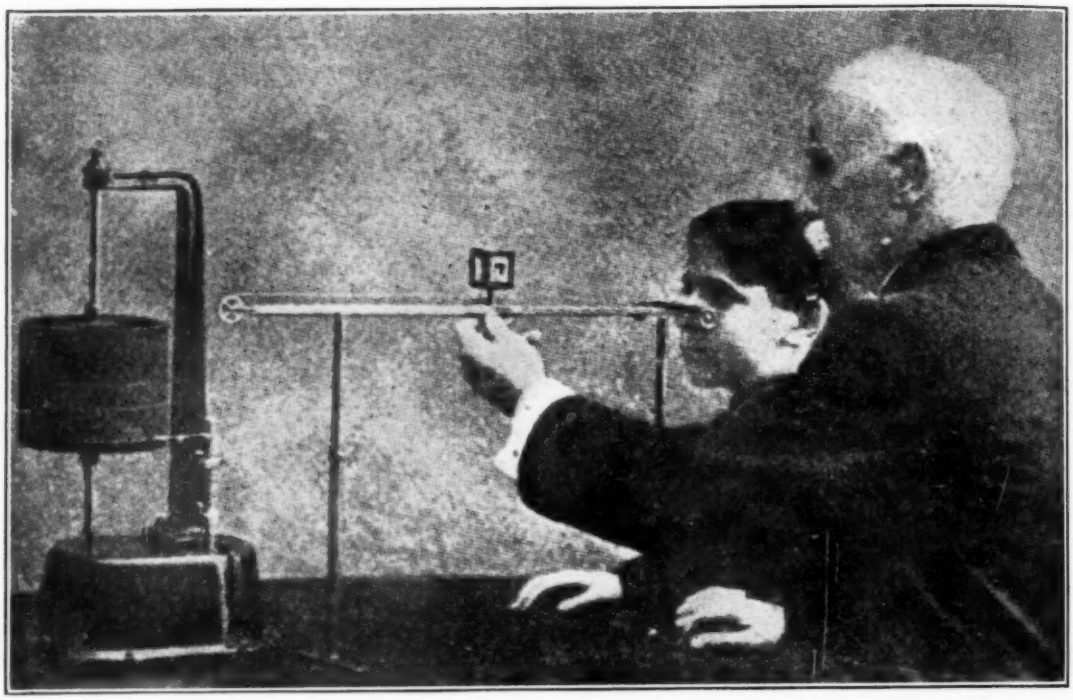


Figure 4

First accommodative ergograph by Howe. It will be noted that this experimenter manipulated the test object. The record was plainly seen by the subject. The test object and rate of movement was not standardized. (Courtesy Howe), from Amer. J. Ophth.

the reaction time in fractions of a second. In this hook up was included a voice key for measuring the sound vibrations from reading out loud,

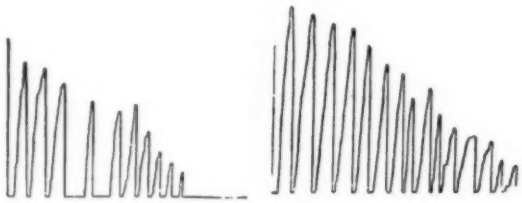


Figure 5

Figure 5 represents two accommodation fatigue records of normal eyes. (Howe).

which were recorded on a smoked drum. Thus, when fatigue set in, the speed of perception was reduced and so recorded. He claims that some persons possess a high resistance to fatigue, while others again are very susceptible to it. Also individuals differ greatly to their average accommodation fixation time. In the less resistant types, he claims, fatigue tends to increase the variableness of the muscular adjustment. Wagner

like most of the other investigators failed to measure the actual amount of accommodation his subjects had before the experiment in order to determine the exact condition of accommodation in each case.

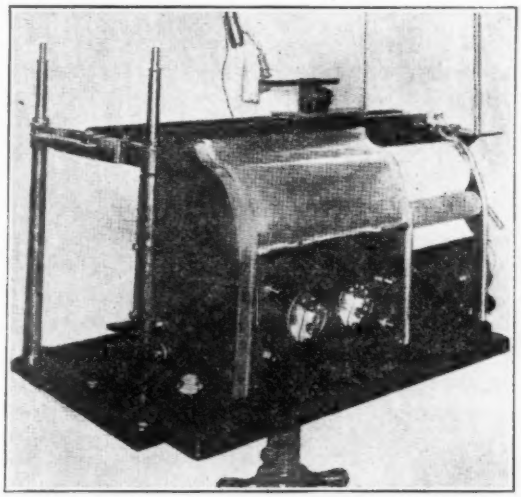


Figure 6

This is one of the latest models of ocular ergographs. It is possible to make a separate record of accommodation and convergence fatigue and to determine which function is affected first. The rest period is controlled by a timing device. The test object and the recording paper are activated by the same motor. Illumination is standardized.

Figures 5 and 6 are reproduced through the courtesy of the American Journal of Ophthalmology.

C. *The Accommodatometer*

Blatt[42] from Romania in his studies of the weakness of accommodation, devised the accommodatometer which he used to measure the amplitude of accommodation. The usual method of bringing the small size type near to the eyes is not an accurate measure of this function, he holds, because there is great variation in the accommodative near point. In a number of cases that he tested he found that the ponctum proximum has no constant value even in subjects with normal accommodation; that slight variations depend upon physiologically variable conditions of the system. Blatt's fatigue curve indicates that it took considerably longer than two to six minutes for his subjects to show fatigue and that it required one hour for complete recovery.

d. *Illumination and Fatigue*

Luckiesh and Moss[46] at the Nela Research Laboratories developed an Ophthalmic Convergence Ergograph which they use in studying the effect of various quantities and qualities of illumination upon the extrinsic ocular muscles and they found that under certain illumination the convergence efficiency decreased from six to eight per cent. This fatigue resulted after performing a severe and fairly critical task for one hour. The same authors also studied fatigue of accommodation under different

kinds of illumination and they found a decrease in the amplitude of accommodation after reading for some time under low illumination.

III. EXPERIMENTAL

A. *The Ocular Fatigue Problem*

In studying this subject of ocular fatigue the following questions present themselves:

1. Is there an actual decrease in the amplitude of accommodation, i.e., accommodative fatigue after severe exertion of accommodation?

2. If we do get accommodative fatigue, is it of peripheral or central origin?

3. Is there an increase in the dioptric power required to perform the same accommodative act after severe ocular exertion than before?

4. If fatigue is developed after severe ocular exertion for a given time would the amount of fatigue increase if we doubled the length of time the eyes are used under the condition of exertion?

5. Are fatigue symptoms a valid index of the existence of fatigue? To enable us to answer some of these questions this experiment was undertaken.

B. *The Experiment*

1. *Laboratory and Illumination*

All of the subjects were tested in the Physiology Laboratory at the University of Minnesota under identical uniform conditions. The illumination was constant between 12 to 18 foot candles, and was only reduced somewhat during the time the dynamic skiascopy test was performed.

C. *Apparatus and Equipment*

1. Tait Dynamic Skiascope.
2. The Phoroptor.
3. The Card for Testing Accommodation.
4. The Ophthalmograph: This is an instrument which photographs on a moving picture film, the behavior of the eyes during the act of reading. It thus furnishes us with a record from which we are able to study the efficiency of the eyes in their ability to read, the speed of reading and the comprehension. It is the only method available at the present which can furnish us information about the behavior of a pair of eyes in the dynamic state, all other available tests furnish information about the eyes while in a static or stationary condition.

The Ophthalmograph is made up of two parts (a) the head rest and (b) the camera. It is mounted on a stand as illustrated in Figs. 8 & 9.

We wish to acknowledge our indebtedness to the Scientific Department of the American Optical Company, Southbridge, Mass., for the kind permission of the use of some of the illustrations. (Figs. 8 to 15 inclusive.)

The Instrument

(A) Head Rest Temple Adjustment. (B) Headrest Forehead Adjustment. (C) Headrest Chin Adjustment. (D) Focusing Telescope—Adjusting in and out and rotatable in all directions. (E) Lamp Casing. (F) Reading Card Holder. Cover card holder contains directions for patient. After directions are read this card is lifted and the test made with reading card in bottom holder. (G) Compartment containing un-

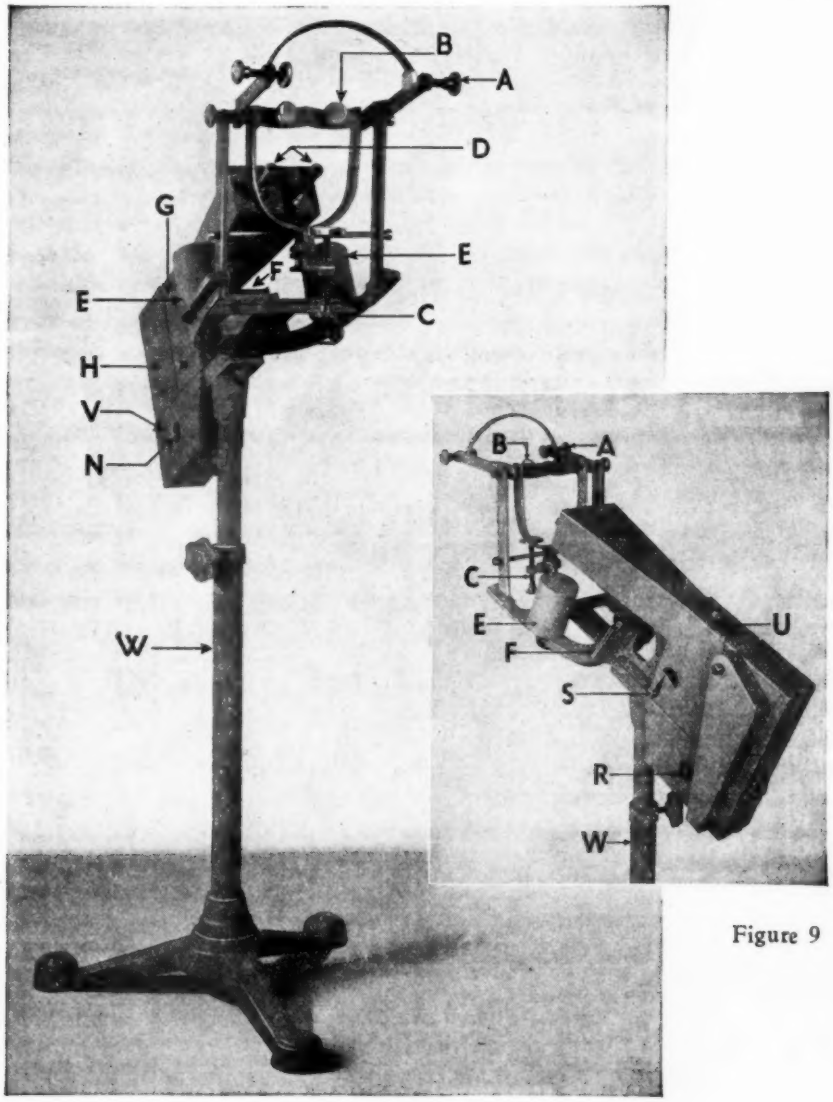


Figure 8

Figure 9

used film. To be opened only for reloading. (H) Compartment containing exposed film. (R) Motor Switch. (S) Indicator shows amount of unused film. (W) Adjustable stand, counterbalanced by spiral spring in stand sleeve.

The principle employed in the Ophthalmograph is easily seen in Fig. 10. The subject reads the card at F which is illuminated from lamp E. Rays of light from lamp E are reflected by the cornea of each eye and these reflected rays are focused by lenses of the telescope under the film.

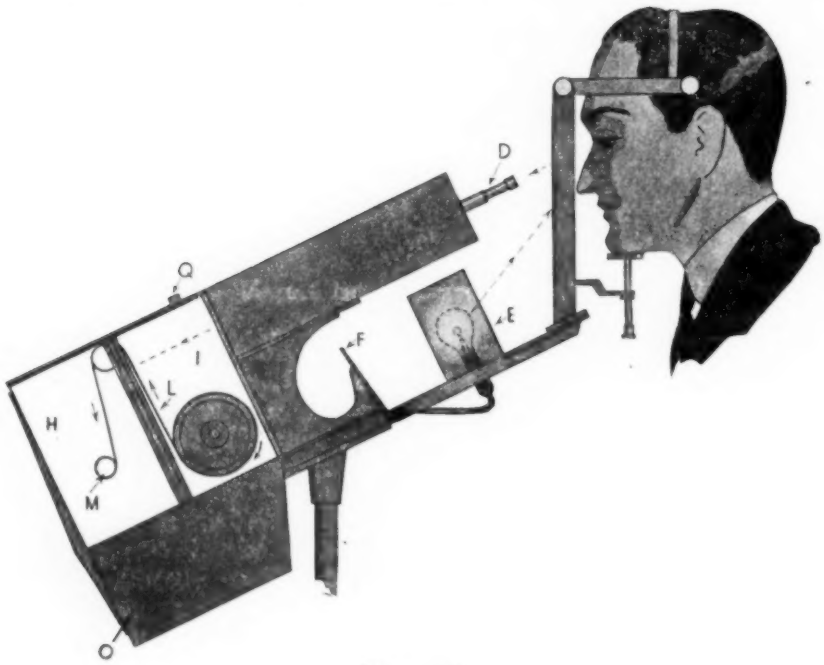


Figure 10

This film travels through the camera upward at a fixed speed of *one-half inch per second,* while the eyes move horizontally across the line of

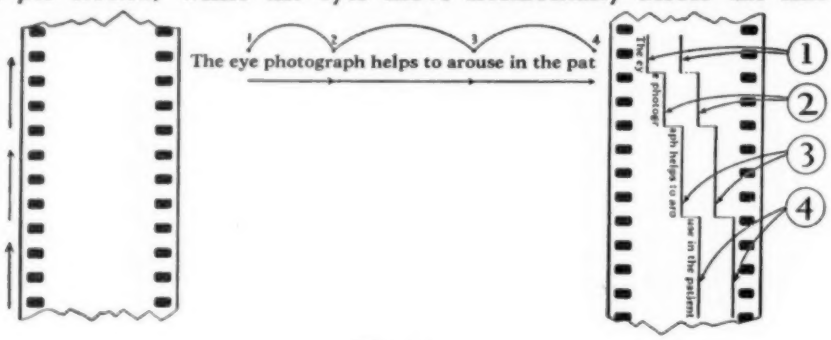


Figure 11

print. The movements on each line are so recorded that the record appears like a double stairway as illustrated in Fig. 11.

Figure 12 illustrates how each movement of the eyes to the left and each fixation produce a record of uniform *"steps."* Figure 12 is the record made by a pair of normal eyes in reading three lines of print, and in

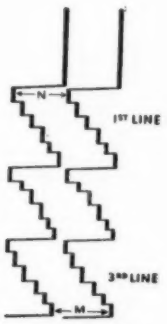


Figure 12

Fig. 13 are indicated the regressions. Instead of the eyes moving regularly to the right as in Fig. 12 they now and then take a move back to the left; this may be due to the fact that the subject did not understand the word or words he read and had to turn back. The return sweep is marked at the place where the subject completed reading the first line and the eyes made a return sweep to the left to begin reading the second line.

D. *Technique Used*

a. *The Tait Dynamic Skiascope was used*

In measuring the amount of accommodation used in the act of reading at a given point, the subject was instructed to fix the smallest letter on the target on the instrument and plus lenses were turned in the phoroptor until the skiascopic shadow movement in the eye was reversed, i.e., until we obtained an against motion. The amount of plus lens in the phorotor at that time measures the maximum amount of accommodation used at the point of fixation. The point of fixation used for all subjects and for all other tests was set at 1/3 meter distance.

b. *Method Used in Testing the Amplitude of Accommodation*

Here we used the card with the very fine type and minus lenses were placed in the phoroptor before the eye until the type completely blurred out, the amount of minus lenses was then reduced slightly until we reached the visibility threshhold so that the subject could read the type on the test card with difficulty. The amount of minus lens power before the eye plus 3.00 diopters of accommodation used at the point of fixation at 1/3 meter was taken as the measure of the amplitude of accommodation.

E. *Method of Work*

1. *Subjects.* In this investigation seven subjects were used all of them between the ages of 20 and 30 years. The time the subjects had to spend during each experimental period ranged from 1½ to 2 hours.

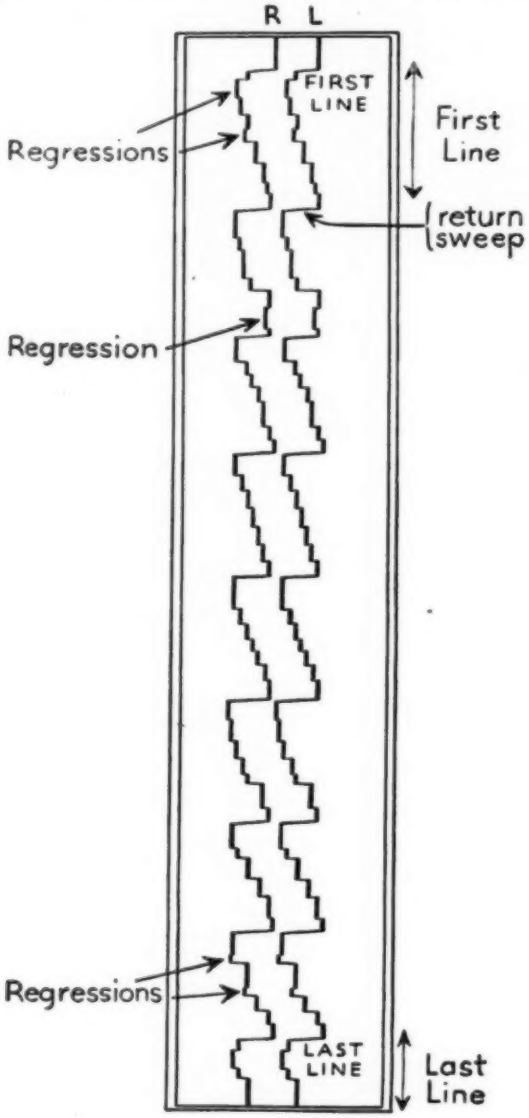


Figure 13

Care was taken to eliminate any subject who had marked refractive abnormalities. Where slight refractive errors were present they were corrected.

2. *Controls.* Each subject acted as his own control. At the beginning of each experimental session a test was made of the dynamic skiascopy, amplitude of accommodation, exophoria, adduction and abduction and the findings were recorded as the first control test. Half an hour later a similar test was made and recorded as the second control test. The subject did not use his eyes during the half hour between the first and second control test. After completing the second control test the subject was given material to read under conditions which he had to use practically all of his available amplitude of accommodation. At the end of half an hour reading a test was again made of his dynamic skiascopy, amplitude of accommodation, exophoria, adduction and abduction. After this test was completed the subject was again given material to read under the same conditions as under the first fatigue test and at the end of half an hour a test similar to the first test was performed.

3. *Directions and Instructions*

a. *Dynamic Skiametry.* This being a purely objective test, no special instructions had to be given to the subject other than to read the letters and figures on the fixation target. The findings of the first and second control tests are recorded in table 1, columns a and b respectively. The findings of the first and second fatigue tests are recorded in columns d and e in table 1.

b. *Amplitude of Accommodation.* In this test the reading card and the phoroptor was used. The card was placed in the card holder which is movable on the rod extending in the front of the phoroptor. Each eye was tested separately, minus lenses were placed in the front of the eye under test until the type became completely "blurred out" and the subject was instructed to say "gone" when he could no longer make out the fine type of the test card, this power of the minus sphere was then reduced by .25 or .50 of a diopter until the subject could barely make out some words on the test card, the subject at this point was to report "I see it," the amount of sphere as given in the phoroptor cell plus the 3.00 allowed for the accommodation distance of 1/3 of meter was taken as the total amplitude of accommodation. For example, if it took minus 5 diopter sphere to cause a complete blur of the type, and this had to be reduced by .5 diopter sphere before the subject could begin to make out some words on the card and report "I see it," then we had (—5.00 D.S. —3. D.S.) — (—.50 D.S.) = 7.5 Diopter Sphere which is the measure of the Amplitude of Acommodation. There were two control and two fatigue tests made at half-hour intervals and these were recorded as shown in Table 2. The control test in columns a and b and the fatigue test in column d and e.

c. *Ophthalmograph.* With this instrument an objective record is made of the dynamic condition of the eyes during the act of reading. After the images are focused and the telescopes adjusted the subject is instructed to fix his eyes on Number 1 and hold his eyes fixed at that point for 2 or 3 seconds until he is told to fix on number 2 of Fig. 14;

after fixing for 2 or 3 seconds on number 2 he is instructed to begin reading and when he completes reading the given paragraph he is to fix his eyes on number 3 and then on number 4 for 2 or 3 seconds and he is then to close his eyes. As the subject first fixes upon number 1 (Fig. 14) the motor of the ophthalmograph is turned on and thus the photographic film begins to move upward at the fixed speed of .5 inch per second. As the subject fixes on numbers 1 and 2 (Fig. 14) the beam of light reflected from his cornea and focused upon the film makes a record of the fixed position of the eyes at numbers 1 and 2. This produces two straight lines preceding the reading and 3 and 4 produce two straight lines following the reading.

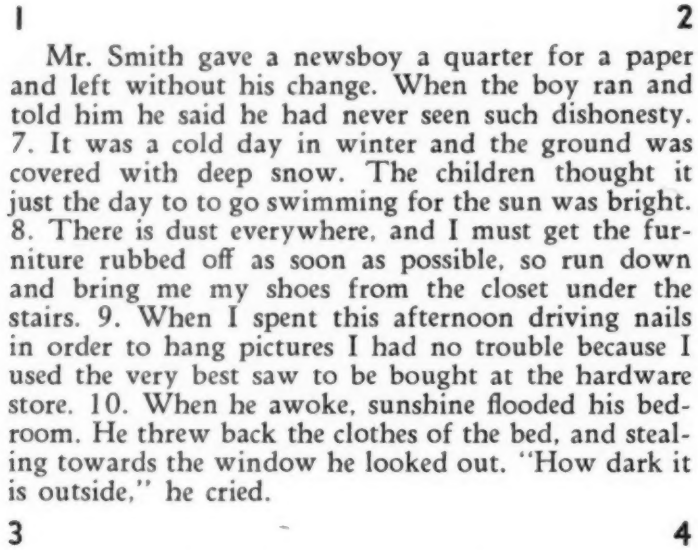

1
2
Mr. Smith gave a newsboy a quarter for a paper and left without his change. When the boy ran and told him he said he had never seen such dishonesty. 7. It was a cold day in winter and the ground was covered with deep snow. The children thought it just the day to to go swimming for the sun was bright. 8. There is dust everywhere, and I must get the furniture rubbed off as soon as possible, so run down and bring me my shoes from the closet under the stairs. 9. When I spent this afternoon driving nails in order to hang pictures I had no trouble because I used the very best saw to be bought at the hardware store. 10. When he awoke, sunshine flooded his bedroom. He threw back the clothes of the bed, and stealing towards the window he looked out. "How dark it is outside," he cried.
3
4

Fig. 14. Ophthalmographic reading card.

This gives the eyes a chance to get adjusted and ready for the reading and enables us to tell exactly when the subject started and ended the task of reading.

IV. Results

A. *Statistical Analysis of the Experimental Findings of Subject H*

1. The Dynamic Skiametry findings are given in Table I. Here are recorded the two control tests in columns a and b, in column c is given the average of the two control test $(a+b/2)$, the two fatigue tests are recorded in columns d and e, in columns f, g, and h are recorded the differences between the first fatigue test and the control test, the difference between the second fatigue test and control, and the differences between the second and first fatigue test respectively. This plan of recording was uniformly followed out in Tables 1 to 5, inc. Sixteen control tests

and a like number of fatigue tests were performed on subject H. In Table 1 columns f and g we find the mean difference between the first fatigue test and control and that of the second fatigue and control test to be .055 diopter and .007D and the S.D. (standard deviation) .127 and .163 respectively. The mean of the difference between the second and first fatigue test is .047 D and S.D. .073 (the word diopter will be designated by D and prism diopter by this symbol △.) To determine the significance of the standard error of the difference of the mean we used this formula for the small sample.

$$t = \frac{x}{s}\sqrt{N\text{-}1}$$

x = The mean of the difference.

s = Standard deviation of the small sample.

N = Number of tests in the sample.

t = ratio of difference between mean to the standard deviation of the difference to be used when the sample is small.

P = Probability that the mean will not be different, or will be exceeded solely through random error of sampling.

The value of P we can obtain from tables for biometricians, if we once determine the value of t. In Table 1, column f, we find that P is much greater than .5; this indicates that the mean will vary in over 50 per cent of the cases. This makes the value of the mean merely a chance proposition. In columns g and h the value of P is .2658 and .1236 which indicated that the mean may be different in 26 and 12 per cent of the cases respectively.

The answer we are interested in this is: Does the subject H use more accommodation at the reading point after exerting his eyes to the limit for ½ hour than he did before, i.e., does he use more accommodation in the fatigue test than he did in the control? The answer is self-evident, when we consider the very small values of means in columns f, g, and h, Table 1. .05, .04 or .007 of a diopter is a very insignificant amount when we consider that the total amount of accommodation used ranges between 3.25 D. and 3.75 D.

We may therefore state that there is very little difference in the amount of accommodation subject H used before and after ocular exertion.

2. *Amplitude of Accommodation.* Findings are given in Table No. 2. Here we find in columns f, g and h the mean of the difference to be 2.430 D.; 2.657 D. and —0.263 D.; the S.D. .618; .669 and .234; the values of P = .0002 and in .0200 in colums f, g and h respectively. This indicates a probability that the mean as given in columns f and g would differ in 2 out of 10,000 cases and in 200 out of 10,000 cases in column h which is the difference between the second and first fatigue test. It will be noticed that as the value of t increases the value of P decreases and approaches a value of zero.

Subject H

Table I
DYNAMIC SKIASCOPY
Measured in Diopters Sphere

		Control Tests			Fatigue Tests		Difference due to Fatigue		
		a	b	c	d	e	f	g	h
Date	Time Exp. Started	1st Test	2nd Test	a+b/2	1st Test	2nd Test	f=d-c	g=e-c	h=e-d
10/30/35	9.00 A.M.	3.25	3.50	3.37	3.62	3.50	0.25	0.12	−0.12
11/6	8.30 A.M.	3.50	3.50	3.50	3.37	3.62	−0.12	0.12	0.25
13	8.00 A.M.	3.62	3.62	3.62	4.00	3.62	0.37	0.00	−0.38
19	7.00 P.M.	3.50	3.39	3.43	3.50	3.75	0.07	0.32	0.25
27	8.20 A.M.	3.50	3.75	3.62	3.75	3.50	0.13	−0.12	−0.25
12/4	8.20 A.M.	3.75	3.87	3.83	3.75	3.50	−0.08	−0.33	−0.25
12/11	8.50 A.M.	3.75	3.75	3.75	3.50	3.62	−0.25	−0.12	0.12
12/20	5.00 P.M.	3.75	3.62	3.68	3.75	3.75	0.07	0.07	0.00
Mean							.055	.0075	− .0475
S.D.							.127	.1630	.073
t							.013	1.2167	1.719
P							.5	.2658	.1236

Subject H

Table II
AMPLITUDE OF ACCOMMODATION
Measured in Diopters Sphere

		Control Tests			Fatigue Tests		Difference due to Fatigue		
		a	b	c	d	e	f	g	h
Date	Time Exp. Started	1st Test	2nd Test	a+b/2	1st Test	2nd Test	f=d-c	g=e-c	h=e-d
10/30/35	9.00 A.M.	7.87	7.75	7.81	6.12	6.25	1.59	1.56	.12
11/6/35	8.30 A.M.	7.75	8.00	7.87	4.37	4.00	3.50	3.78	− .37
11/13/35	8.00 A.M.	7.75	8.00	7.87	6.00	5.50	1.87	3.37	− .50
11/19/35	7.00 P.M.	7.87	8.00	7.93	5.75	5.75	2.18	2.18	.00
11/27/35	8.20 A.M.	7.37	7.25	7.31	4.37	4.25	2.94	3.06	− .12
12/4/35	8.20 A.M.	7.25	7.25	7.25	5.37	5.00	2.25	2.25	− .37
12/11/35	8.50 A.M.	7.12	7.12	7.12	5.25	4.62	2.87	2.50	− .62
12/20/35	5.00 P.M.	6.87	7.50	7.18	4.87	4.62	2.31	2.56	− .25
Mean							2.430	2.657	− .263
S.D.							.678	.669	.234
t							15.717	27.503	2.970
P							.0002	.0002	.0200

In view of the fact that the value of P is so small and that the value of the mean of the difference is 2.4 D. and 2.6 D. respectively it would indicate that the efficiency of the amplitude of accommodation is considerably decreased after ocular exertion for 30 minutes and that the amplitude of accommodation was not decreased any more during the second 30 minutes work; as a matter of fact it was increased by .26 D.

3. *Analysis of Ophthalmographic Record of H*

In the preceding pages data was presented and analyzed to show what possible effect extreme ocular exertion has upon (a) the amount of accommodation used at the near point and (b) the amplitude of accommodation. It was shown that there was a decrease in the amplitude of accommodation after a 30 minute work period. The question that presented itself: Does this work cause only peripheral fatigue or does it also produce central fatigue? We decided to make some ophthalmographic records with the hope that this may throw some light on the subject. We have therefore made a photographic record with the ophthalmograph (see Figs. 8 to 13 inc.) to determine the subject's capacity for reading at the beginning and end of a 30-minute period. During that period we made the subject exert his accommodation to the limit the same as we did in the other tests, as a matter of fact these photographs were made during the same experimental period when the other control and fatigue tests were made. Figs. 15 and 16 are the ophthalmographic records of the control and fatigue test respectively. Analyzing these records we find the following:

Table III

Analysis of Ophthalmographic Graph of Subject H

	Control	Fatigue	Difference
Time in sec. required to read 150 words	28.00	32.24	4.24
Number of words read per minute	321.43	282.94	38.57
Number of fixations per 150 words	105.00	117.00	12.00

From the analysis of the graphs we find that subject H had to spend 4.24 seconds more to read 150 words at the end of the 30 minute period of work, than he did at the beginning, and could read 282.94 words per minute that is 38.57 or 13.16 per cent less than he could at the beginning of the period during the control test. He also had to make 12 more fixations during the fatigue test than during the control.

Parts a and b of Fig. 15 make up the control record. Subject began reading at the point marked 1 and completed at point 2. It will be observed that subject's eyes were not stationary when he fixed his eyes on a point after he completed reading. The eyes had a kind of nystagmus movment for about 3 seconds as is shown on the record between points 2 and 3. Then the eyes came to a stand still as is shown by the straight line between points 3 and 4.

Parts a, b and c, Fig. 16 make up the total fatigue record. Here again reading started at point 1 and stopped at point 2. The nystagmus movement between point 2 and 3 is more marked on the fatigue record than on the control record. The fatigue record indicates that at the end of the 30-minute period his reading efficiency was definitely decreased and may suggest the presence of fatigue. These objective results are in agreement with the subjective results found in the amplitude of accomodation (see Table 2).

A. *Increasing the Sample*

The question that now presents itself is this: If we should make these same tests upon another subject or on a number of subjects would we get the same results or different results? Psychologists and Biometricians are contending that it is not safe to draw conclusions from one subject only and advise that the sample be random and representative. For this reason we have added six more subjects and we shall now try to analyze the results of the whole group.

B. *Statistical Analysis of the Experimental Findings of the Other Six Subjects*

1. *Dynamic Skiametry*

In Table No. 4 are recorded the results of the dynamic skiametry findings. Each one of the Tables 4 and 5 are divided into three sections: A, B, and C respectively. In section A the mean, S.D., t, and P values are given for the difference between the first fatigue test and control; in section B these values are given for the difference between the second fatigue test and the control test, and in section C the values are given for the difference between the second and first fatigue tests.

Upon examining section A, Table 4, we note that the values of the mean are very low, the highest being .17 D. and the lowest 0.00. The values for P are greater than .5 for five subjects, nearly .5 for the sixth subject and only for one subject is the value of P equal to .0018. This indicates that in 6 out of 7 cases the value of the mean is merely a matter of chance and will differ in well over 50 per cent. In section B we again find a very low value for the mean ranging between .007 D. to .253 D. The values for P for three subjects are greater than .5, for one nearly .5 and the values for the other three subjects are rather high, and the same holds true for the values in section C. Considering that the values of the mean of the difference is so small there is no indication that more accommodation is used at the end of the experimental period. This agrees quite well with the dynamic skiametry findings for subject H.

2. *Amplitude of Accommodation*

If we now analyze Table 5 we find in section A that only subject H had an appreciable difference in the amount of amplitude of accommodation at the end of the experimental period, the mean being 2.43 D., the rest of the six subjects had an insignificant difference, the mean ranging from .010 D., the lowest, to .50 D., the highest. The value of P is

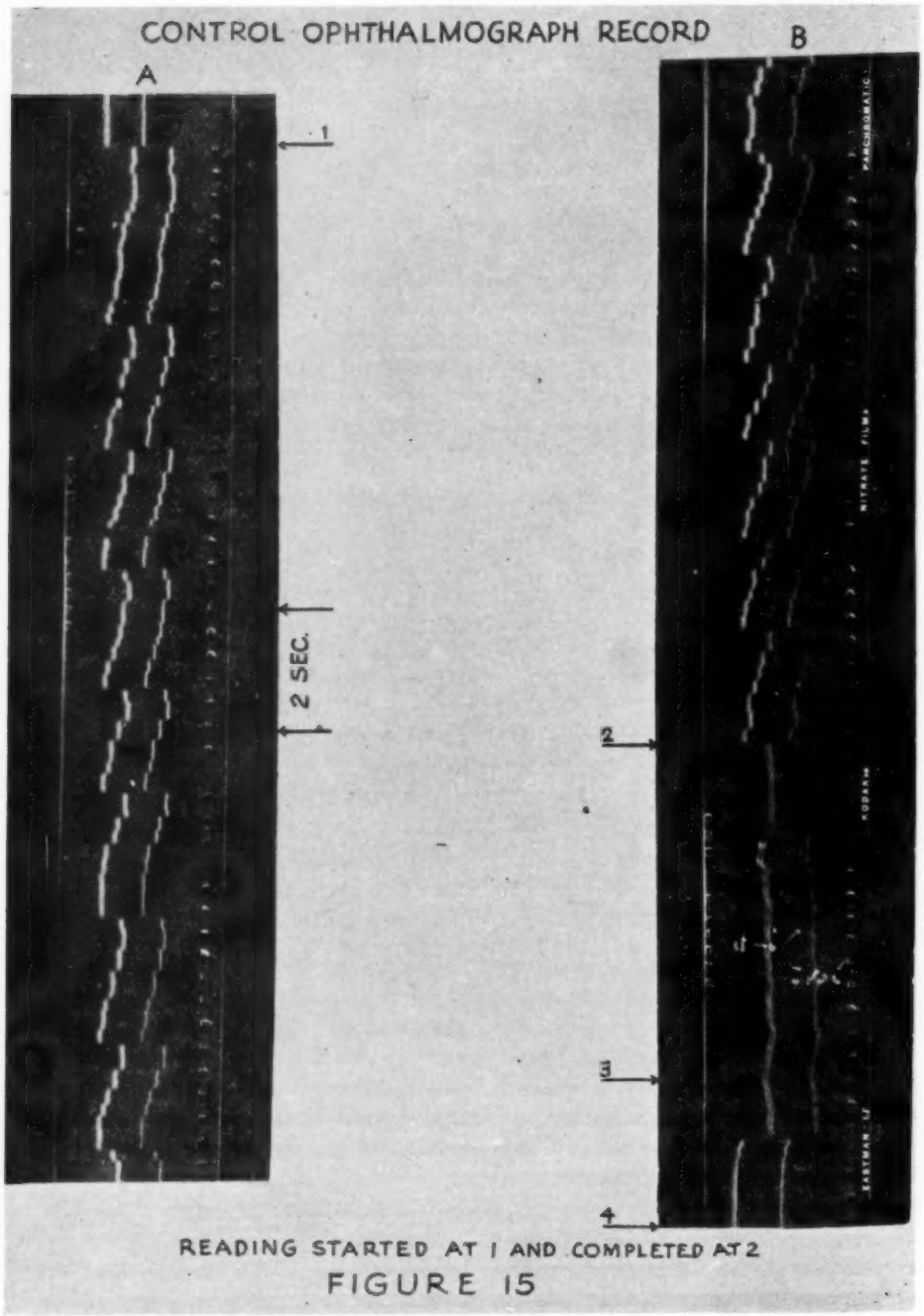


FIGURE 15

The two sec marked on the graph represent 2 inches on the original graph.

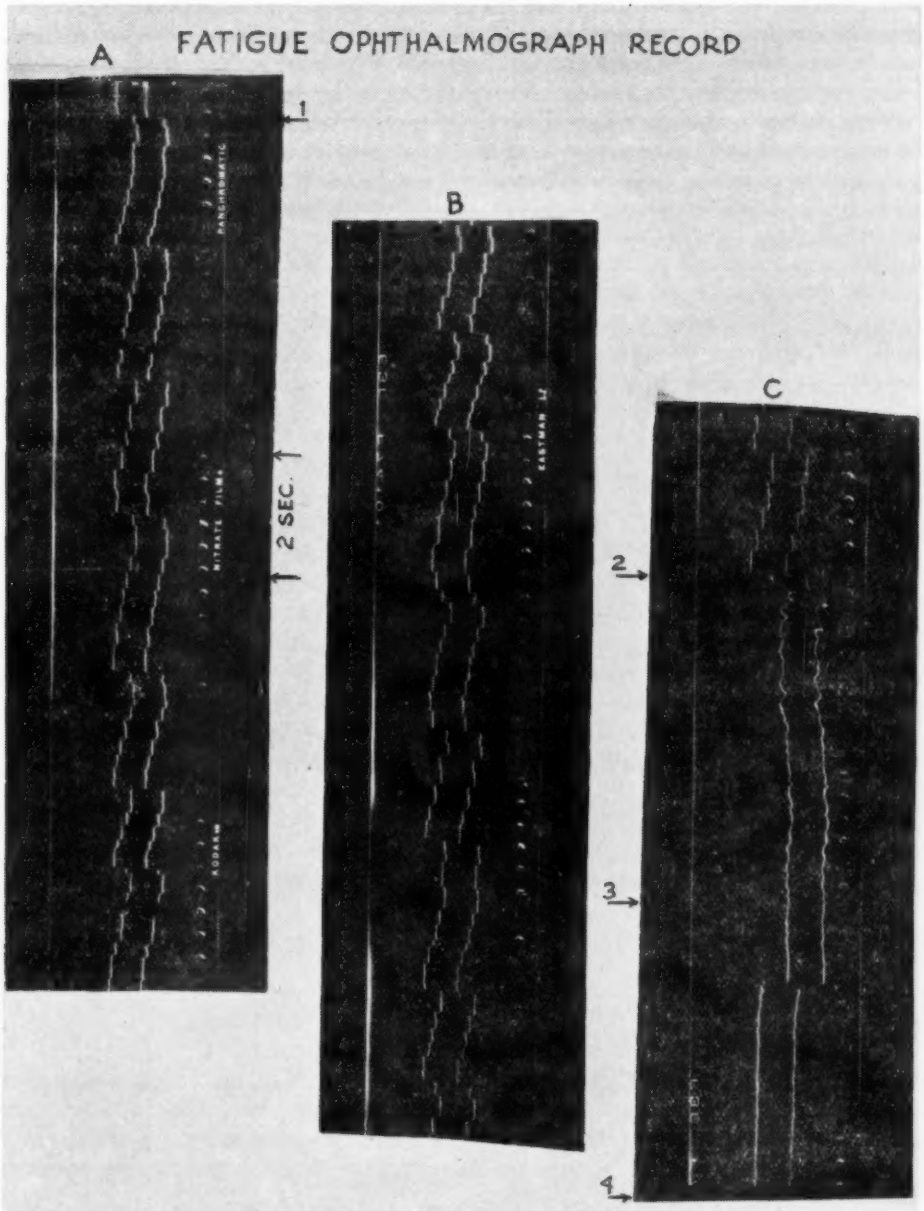


FIGURE 16

The two sec' marked on the graph represent 2 inches on the original graph.

Table IV

Differences in Dynamic Skiametry Due to Fatigue

	A				B				C			
	Difference between first Fatigue Test and Control				Difference between second Fatigue Test and Control				Difference between second and first Fatigue Test			
Subject	Mean	S.D.	t	P	Mean	S.D.	t	P	Mean	S.D.	t	P
H	.055	.127	.013	>.5	.0075	.1630	1.2167	.2658	− .047	.073	1.719	.1236
S.C.	.170	.010	24.030	.0018	.113	.04	3.990	.0570	.083	.140	.9610	.4352
A.E.	.020	.202	.139	>.5	.023	.144	.224	>.5	.044	.212	.292	>.5
G.D.	.166	.201	1.110	.4512	.207	.154	1.900	.1536	.040	.060	.930	.4214
A.B.	.124	.302	.710	>.5	.155	.477	.860	.4535	.095	.433	.370	>.5
L.S.	.093	.925	.141	>.5	.253	.689	.518	>.5	.333	.313	1.500	.2724
M.H.	.000	.03	.240	>.5	.166	.500	.469	>.5	.000	.000	.000	.000

Table V

Differences in Amplitude of Accommodation Due to Fatigue

	A				B				C			
	Difference between first Fatigue Test and Control				Difference between second Fatigue Test and Control				Difference between second and first Fatigue Test			
Subject	Mean	S.D.	t	P	Mean	S.D.	t	P	Mean	S.D.	t	P
H	2.430	.618	15.717	.0002	2.657	.669	27.503	.0002	− .263	.234	2.970	.0200
S.C.	.035	.137	3.61	.0689	.520	.077	9.54	.0110	.170	.114	2.108	.1706
A.E.	.083	.513	.227	>.5	− .083	.259	.460	>.5	.333	.456	1.063	.3500
G.D.	.373	.836	− .613	.6041	− .417	.394	−1.490	.2748	− .040	.388	.145	>.5
A.B.	.130	.664	1.060	.2674	.220	.913	1.830	.1648	.032	.223	.240	>.5
L.S.	.500	.588	1.200	.3530	.580	.389	2.100	.1706	.083	.828	.151	>.5
M.H.	.010	.622	.022	>.5	.253	.470	.760	.5276	.250	.203	.142	>.5

rather high for 4 subjects. Is not so high for subject S.C. and is the lowest for subject H, being .0002. The findings are quite similar in sections B and C of Table 5. This would suggest that H is the only subject in the group who has a significant mean difference between the control and fatigue findings and has a very low value of P, that the probability is that in only two out of 10,000 would the value of this mean differ.

C. *Fatigue Symptoms*

While subject H is the only one who shows a definite decrease in the amplitude of accommodation at the end of a 30-minute reading period, which may be taken as an indication of fatigue, it may be of interest to relate the fatigue symptoms complained of by the various subjects.

(1) Subject H—After reading for 15 minutes complains eyes feel tired, has difficulty in keeping them open, has to force himself to keep the lids open. Feels very tired, and develops headaches at the end of the experimental period. The type fades out periodically.

(2) Subject S.C.—Feels a muscular strain, eyes ache and feel tired. Developed muscular disturbances which made it impossible at times to make the phoria and duction tests.

(3) Subject A.E.—Does not complain of any symptoms.

(4) Subject G.D.—Eyes draw, has difficulty in reading, cannot concentrate.

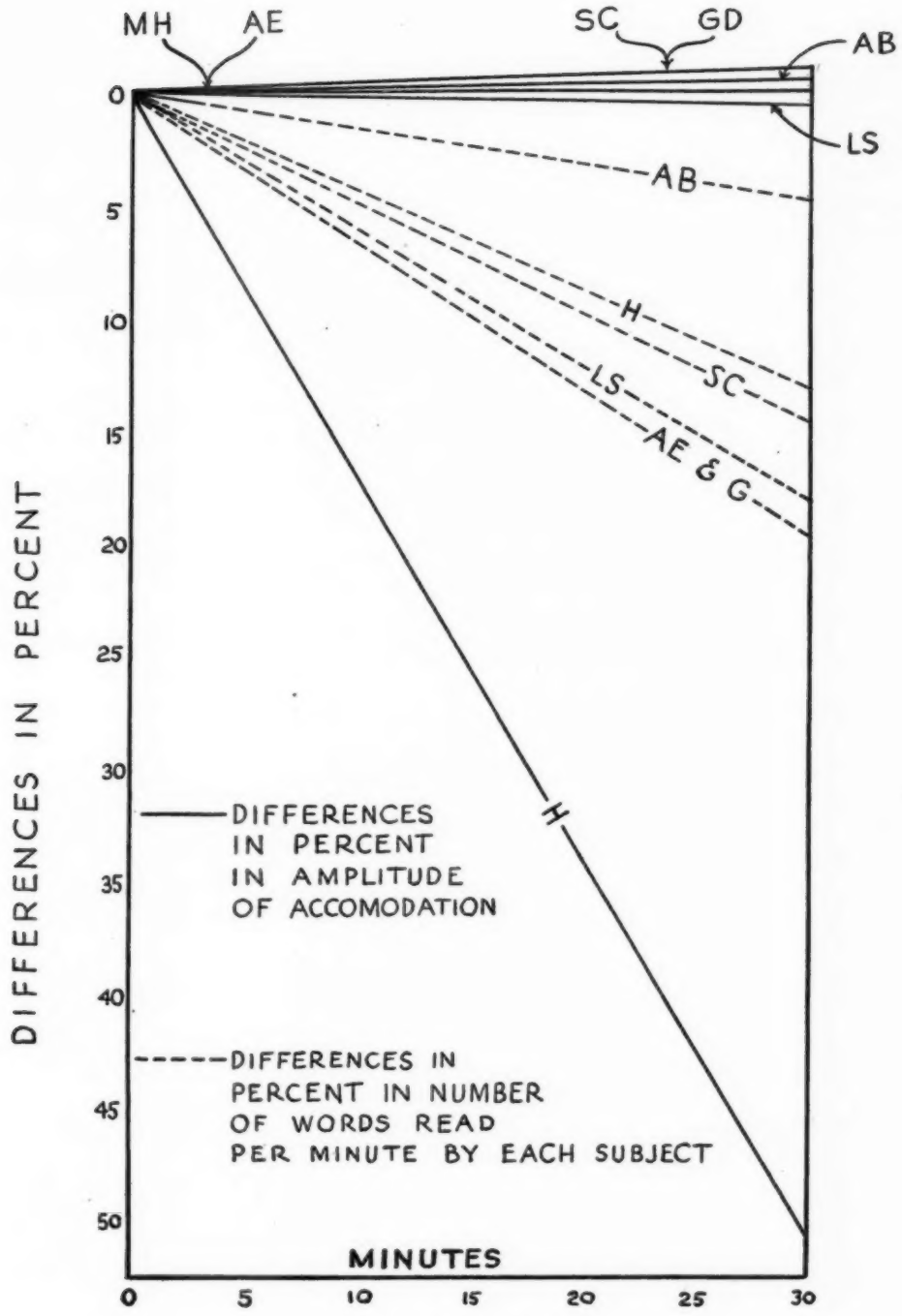
(5) Subject A.B.—Developed diplopia after reading for 20 minutes the first period. Eyes feel tired, had difficulty reading, print disappears at times, had difficulty in making the phoria tests.

(6) Subject L.S.—Eyes feel very tired, feels pain all over his head, feels as if he were having nystagmus. The type fades out at times. Feels nauseated and sleepy, can't keep eyes open. He developed horizontal diplopia which lasted for 20 to 30 seconds; when it disappeared he could not read the type with the same lens, had to give him more plus lens. Feels a pulling effect on both sides of the temples which extends to the back of his head. His reading is intermitant. Developed a vertical diplopia which lasted for about 30 seconds. Developed a marked conjunctivites at the end of half an hour and profuse lacrimation and photophobia.

(7) Subject M.H.—Feels a dull headache which becomes worse as he reads on. Left eye itches and aches. Has difficulty keeping eyes open. Can only read at times but not constantly. The headache is getting very bad. It lasted for several days after each experimental period.

D. *Analysis of the Ophthalmographic Records of the Group*

1. The fatigue symptoms would lead one to suspect that the subjects had fatigue some place in spite of the fact that all tests described earlier did not point that way with the exception of subject H. It may be of interest to analyze the Ophthalmographic records of the group to see whether these will throw any more light on our problem.


MH
AE
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AE & G
H
DIFFERENCES IN PERCENT
0
5
10
15
20
25
30
35
40
45
50
DIFFERENCES IN PERCENT IN AMPLITUDE OF ACCOMODATION
DIFFERENCES IN PERCENT IN NUMBER OF WORDS READ PER MINUTE BY EACH SUBJECT
MINUTES
0
5
10
15
20
25
30

FIGURE 17

2. In Table 6 the record of each subject is given. In section A, columns "a" and "b" record the amount of time in seconds each subject spent in reading one paragraph of 150 words during the control and fatigue test respectively, in column c is recorded the difference in time between the fatigue and control tests. Section B column "d" and "e" record the number of words each subject was able to read per minute during the control and fatigue tests, column "f" records the difference between "e" and "d" and column "g" expresses this difference in per cent. Now if we turn to section B we find in column f that subject S.C. was able to read 38.57 words less at the end of the 30 minute period than at the beginning or a decrease of 13.63 per cent. H read 43.0 less or 14.82 per cent. A.E. and G.D. read 66.66 words less or 20 per cent. Subject A.B. 23.82 words or 5.28 per cent and subject L.S. 73.59 words or 18.94 per cent. The mean for the group difference is 52.05 the ratio of t is 7.02 and P the probability is that the mean would not differ in more than 4 out of 10,000 cases.

In Fig. 17 are plotted the differences between the fatigue and control test of the amplitude of accommodation and of the number of words read per minute, these differences are expressed as given in per cent in Table 7.

Table VI

Analysis of Ophthalmographic Records

		A			B			
		Reading time in Seconds per 150 words			Number of words read per Minute			
		a	b	c	d	e	f	g
Subject	Date	Control	Fatigue	c=b-a	Control	Fatigue	f=e-d	in per cent
S.C.	12/20/35	27.00	30.08	3.08	333.00	290.00	−43.00	14.82
H	2/22/36	28.00	32.24	4.24	321.94	282.94	−38.57	13.63
A.E.	12/21/35	22.08	27.50	4.92	400.00	333.33	−66.67	20.00
G.D.	2/19/36	22.08	27.00	4.92	400.00	333.33	−66.67	20.00
A.B.	3/1/36	19.00	20.00	1.00	473.82	450.00	−23.82	5.28
L.S.	3/1/36	19.58	22.60	3.02	461.28	388.69	−73.59	18.94
	Mean						52.053	
	S.D.						18.033	
	t						7.02	
	P						.0004	

Table VII

Differences in Per Cent Due to Fatigue in the Amplitude of Accommodation and the Number of Words Read per Minute

Subjects	Amplitude of Accommodation	Number of words read per minute
H	—51.00	—13.63
S.C.	+ 0.05	—14.82
A.E.	0.00	—20.00
G.D.	0.05	—20.00
A.B.	0.03	— 5.00
L.S.	— 0.07	—18.94
M.H.	0.01	

It will be readily observed that subject H is the only one who had a considerable decrease in the amplitude of accommodation during the fatigue test, this amounting to 50 per cent, subject L.S. decreased less than one per cent, subject S.C., G.D. and A.B. increased less than one per cent and subjects A.E. and M.H. did not show any change in the amplitude of accommodation between the fatigue and control tests. We thus see from this graph that two subjects had no change, three subjects increased their amplitude of accommodation during the fatigue by less than one per cent, one subject decreased it by less than one per cent. The increase and the decrease in the four cases mentioned was so small that for all practical purposes we may say that in six subjects there was no change in the amplitude of accommodation between the control and fatigue test and in only one subject was there a marked decrease in the amplitude of accommodation. On the other hand if we examined the curves representing the per cent difference in number of words the subjects were able to read we find that there was a definite decrease in reading efficiency of all subjects ranging from 5.28 per cent for A.B. and 20 per cent for subjects A.E. and G.D. This indicates that each subject had a certain amount of fatigue at the end of 30 minutes and that the fatigue was probably of central origin.

SUMMARY

1. A series of tests have been carried out on seven subjects to determine whether they get ocular fatigue by using their eyes for 30 minutes under a task requiring severe exertion.

2. The dynamic skiascopy, Amplitude of Accommodation were tested at the beginning of each experimental period which was designated as the control test and at the end of the 30 minutes experimental period, which was taken to be as the fatigue test. The difference between the fatigue and control tests were calculated as well as the difference between the first and second fatigue test.

3. The data was treated statistically and the mean, S.D. and t values were calculated the P values were then obtained from tables for biometricians.

4. Control and fatigue ophthalmographic records were made to determine whether there was a decrease in the reading efficiency during the fatigue tests.

5. The fatigue symptoms of each subject were listed and these indicated the presence of fatigue.

6. It was found that only subject H had a considerable decrease in the amplitude of accommodation in his fatigue tests, the other six subjects showed practically no change in the fatigue test.

7. All seven subjects showed a marked decrease in reading efficiency.

CONCLUSIONS

From the results discussed and analyzed one may conclude that:

1. Using the eyes under extreme exertion for 30 minutes accommodative tests will not reveal in the majority of cases, any manifest fatigue.

2. After using the eyes for 30 minutes under severe task, fatigue will be manifested upon analysis of the ophthalmographic records, there will also be a manifestation of ocular fatigue symptoms in most cases.

3. The amount of accommodation used at the near point is at the end of the task the same as it is at the beginning.

4. There is no decrease in the amount of the amplitude of accommodation at the end of the 30 minute reading period excepting in the one subject which showed a considerable amount of exophoria at near.

Jack I. Kurtz.

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BOOK NOTICES

AN INVESTIGATION AS TO THE NEED FOR "DROPS" OR CYCLOPLEGICS IN EYE EXAMINATIONS. Carel C. Koch, Chairman, Committee on Refractive Procedure of the Minnesota Academy of Optometry. Published by the American Journal of Optometry, Minneapolis, Minn. 36 pages. Heavy Paper Covers. 50c. 1938.

This monograph deals with the question of cycloplegics and their value in ocular refracting work. The author approaches the subject from the standpoint of the reason frequently offered the public for using drugs in examination work by those who still cling to this practice. He then reviews the entire subject showing first the absence of scientific background for the technique, the lack of controlled experimentation to determine the value of the technique, the utter lack of agreement among medical practitioners on the value of the technique and the evident variability of results which are obtained when drugs are used for this purpose.

He next reviews the controlled experimental work done in this field by Tait and Sinn. These researches indicate clearly the fact that the findings as gotten by means of a cycloplegic examination are so variable as to be of no value to the examiner and in fact are apt to cause confusion rather than assistance in making a diagnosis. The monograph contains much clinical evidence and many supporting statements indicating that the cycloplegic examination technique in ocular work is unnecessary. Important paragraphs are set out in a unique manner and the entire book is one which can easily be read by the layman as well as the professional man.

T. O. B.

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TEXT-BOOK OF OPHTHALMOLOGY. Vol. II. Sir W. Stewart Duke-Elder, M.A., D.Sc. (St. And.), Ph. D. (Lond.), M.D., Ch.B., F.R.C.S. Published by the C. V. Mosby Co., St. Louis, Mo. 992 pages, 742 illustrations and 24 full page color plates. Cloth, $15, 1938.

This book is a splendid supplement to Volume One, dealing as it does with the clinical methods of examination of the eye as well as the congenital and developmental anomalies, the general pathological and therapeutical considerations in eye work to say nothing of fully reviewing the diseases of the outer tunics of the eye. It covers this field of eye disease in the most detailed manner. The book is a large one and is an important addition to the literature and is one which should find ready

welcome in every optometric library. Duke-Elder has performed a truly outstanding achievement in compiling this wealth of material.

C. C. K.

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A TEXTBOOK OF OPHTHALMOLOGY. Sanford R. Gifford, M.A., M.D., F.A.C.S. Professor of Ophthalmology, Northwestern University Medical School, Chicago, Ill. Published by the W. B. Saunders Company, Philadelphia, Pa. 492 pages, illustrated. Cloth. $4. 1938.

This text deals principally with ocular pathology and techniques employed in the diagnosis and treatment of the various abnormalities encountered in doing eye work. While every phase of ocular work is at some time touched upon by the author, the book is one to go into that segment of a library dealing with disease and the therapeutical measures employed to overcome the involvement. Ocular refraction is dealt with in a minor way but the book has its particular merit in those sections dealing with therapeutics. Here the author is at his best and it is in this particular that the volume stands apart from others as an outstanding contribution to ocular literature. C. C. K.

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